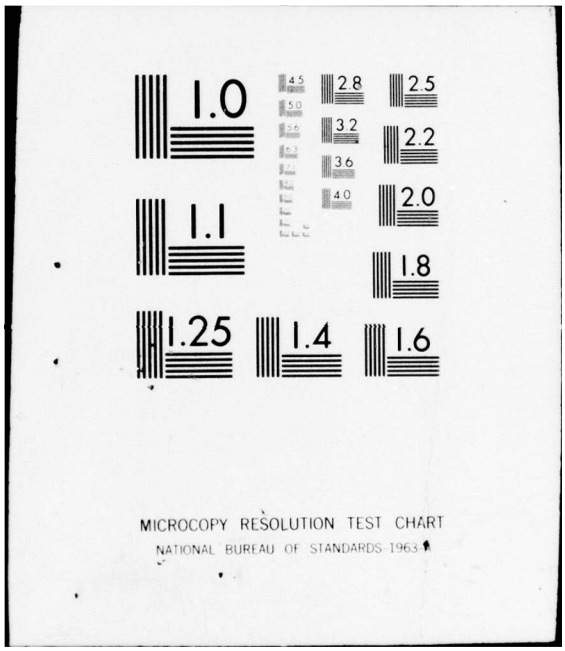
AD-A051 756 FOREIGN TECHNOLOGY DIV WRIGHT-PATTERSON AFB OHIO F/G 6/4
GENERAL PHYSIOLOGICAL ASPECTS OF THE PROBLEM OF THE PERCEPTION --ETC(U)
DEC 77 G F PLEKHANOV

UNCLASSIFIED FTD-ID(RS)T-2173-77 NL

| OF |
AD
A051756

END
DATE
FILMED
5-78
DDC


1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
4.5
5.0
5.6
6.3
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

FTD-ID(RS)T-2173-77

(1)

# FOREIGN TECHNOLOGY DIVISION

## GENERAL PHYSIOLOGICAL ASPECTS OF THE PROBLEM OF THE PERCEPTION OF WEAK SIGNALS BY AN ORGANISM

by

G. F. Plekhanov

# EDITED TRANSLATION

FTD-ID(RS)T-2173-77 13 December 1977

MICROFICHE NR: FTD-77-C-001586

GENERAL PHYSIOLOGICAL ASPECTS OF THE PROBLEM OF THE PERCEPTION OF WEAK SIGNALS BY AN ORGANISM

By: G. F. Plekhanov

English pages: 11

Source: Problemy Obnaruzheniya Slabykh Reaktsiy Nervnoy Sistemy, Moscow, 1968, pp. 24-32.

Country of origin: USSR
Translated by: Robert D. Hill
Requester: FTD/ETCK
Approved for public release; distribution unlimited.





PREPARED BY:

TRANSLATION DIVISION
FOREIGN TECHNOLOGY DIVISION
WP-AFB, OHIO.

## U. S. BOARD ON GEOGRAPHIC NAMES TRANSLITERATION SYSTEM

| Block | Italic | Transliteration | Block | Italic | Transliteration |
|---|---|---|---|---|---|
| А а | *А а* | A, a | Р р | *Р р* | R, r |
| Б б | *Б б* | B, b | С с | *С с* | S, s |
| В в | *В в* | V, v | Т т | *Т т* | T, t |
| Г г | *Г г* | G, g | У у | *У у* | U, u |
| Д д | *Д д* | D, d | Ф ф | *Ф ф* | F, f |
| Е е | *Е е* | Ye, ye; E, e* | Х х | *Х х* | Kh, kh |
| Ж ж | *Ж ж* | Zh, zh | Ц ц | *Ц ц* | Ts, ts |
| З з | *З з* | Z, z | Ч ч | *Ч ч* | Ch, ch |
| И и | *И и* | I, i | Ш ш | *Ш ш* | Sh, sh |
| Й й | *Й й* | Y, y | Щ щ | *Щ щ* | Shch, shch |
| К к | *К к* | K, k | Ъ ъ | *Ъ ъ* | " |
| Л л | *Л л* | L, l | Ы ы | *Ы ы* | Y, y |
| М м | *М м* | M, m | Ь ь | *Ь ь* | ' |
| Н н | *Н н* | N, n | Э э | *Э э* | E, e |
| О о | *О о* | O, o | Ю ю | *Ю ю* | Yu, yu |
| П п | *П п* | P, p | Я я | *Я я* | Ya, ya |

*ye initially, after vowels, and after ъ, ь; e elsewhere.
When written as ё in Russian, transliterate as yё or ё.

## RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

| Russian | English | Russian | English | Russian | English |
|---|---|---|---|---|---|
| sin | sin | sh | sinh | arc sh | $\sinh^{-1}$ |
| cos | cos | ch | cosh | arc ch | $\cosh^{-1}$ |
| tg | tan | th | tanh | arc th | $\tanh^{-1}$ |
| ctg | cot | cth | coth | arc cth | $\coth^{-1}$ |
| sec | sec | sch | sech | arc sch | $\operatorname{sech}^{-1}$ |
| cosec | csc | csch | csch | arc csch | $\operatorname{csch}^{-1}$ |

| Russian | English |
|---|---|
| rot | curl |
| lg | log |

# GENERAL PHYSIOLOGICAL ASPECTS OF THE PROBLEM OF THE PERCEPTION OF WEAK SIGNALS BY AN ORGANISM

G.F. Plekhanov

The definition of the concept "weak signal" as applied to biological systems is given. The qualitative and quantitative indices of the signal as a material information carrier are determined. Cases of the effect of a stimulus on a living organism are classified.

The problem of the perception of weak signals by an organism from a methodological viewpoint is broken down into a number of elementary positons, which are in need of a clearer description and definition. The need for such a work is created by the fact that the lack of understanding due to the terminological discrepancies can greatly complicate the investigations and exchange of opinioun in this direction. Therefore, it is expedient from the very beginning to attempt to give as accurate characteristics of the terms used here as possible, to introduce the acceptable classification of the concepts, and to limit the sphere of their applicability as clearly as possible.

The term "weak signal" is borrowed from the phyciotechnical disciplines, where it has the meaning of "a signal which is comparable or found below the level of noise." For physiology such a definition is not always sufficient, since a considerable part of the technically "strong" signals can prove to be "weak" physiology (signals of radio communication and television, electrical, magnetic fields, and so on). It is natural to consider the physiologically weak signals which are found on the threshold or under

the threshold of perception by the organisms. However, different organisms have different ranges and thresholds of sensitivity, and therefore if we take the given formulation, it would be necessary to point out additionally for which kind of animals the signal is weak. It is convenient to use the subjective sensitive of man as the general physiological characteristic. In this case the signals not perceivable by man can be considered to be weak. This definition requires a clearer classification of the natural signals from a physiological viewpoint.

The term "signal" has a double meaning: information and energy. As a carrier or element of information it is determined by purely informational criteria without reference to the specific material form of its existence, and here concepts of isomorphism, coding and so on are applicable. At the same time each real signal has a completely defined material base and can be considered as the manifestation of one or another form of the movement of matter. Unlike the informational characteristics, examined sufficiently in detail by the information theory, the energy affiliation of the signal is considered considerably weaker, although the role of its individual particular cases is sufficiently great. Thus in the development of the specific receiving device, there is considerable importance in not only the information content of the signal but also its energy nature (electromagnetic, sound optical, etc.). It is especially important to consider its energy nature in the study of the perception of the perception of weak signals by the organisms or signals not perceivalbe by man. Furthermore, the theory of the structure of the signals was developed predominantly for the satisfaction of requests of technology, communication theory, and information theory, and therefore the main attention was given to the artificial signals designated for the transmission of information to a definite device. The different organisms, in particular, man, for the perception of the surrounding environment are forced to use for the most part natural signals, irrespective of their existing signals. Corresponding to this, the accepted definitions and classifications can not be

unconditionally used in the study of the perception of signals by organisms.

A more extensive definition of the signal is given by F.P. Tarasenko [1, 2]. "Any state of a physical object can be considered as a signal." It refers to the natural signal but covers practically all the actually existing signals. However, for the refinement of the concept, it is expedient to replace the word "physical" by the word "real," since the different chemical, biological and psychological states, which have great meaning for the living beings, are not always simply imagined as a physical state. Furthermore, it is useful to add the expression "and change of states" to the term "state." This addition, which ensues naturally from the context of the cited works, must be made because many organisms react not so much to the state as to the change in the state of the object. In final form the definition of the signal can be given in the following way: any state or any change in the state of any real object can be considered as a signal.

According to the existing classifications, the signals are subdivided into two classes: 1) static - designated predominantly for the storage of information; 2) dynamic - intended predominantly for the transmission of information.

Furthermore, a number of parameters of the signal are distinguished: 1) structural parameters - which characterize the number of degrees of freedom of the signal ; 2) parameters of sampling or parameters of distinction, which inform about the affiliation of the given signal to a certain group; 3) informative parameters, which are designated directly for the representation of the information being transmitted.

Finally, three types of signals are distinguished: 1) communication signals or direct signals; 2) signals of measurement; 3) natural signals, i.e., signals not generated for any purpose but actually existing.

This classification, just as any other, is conditional to a certain degree and is not completely convenient for the study of the physiology of equipment for analysis. The main discrepancy lies in the fact that the classes, types and parameters of the signals are distinguished here as different groupings of the signals, which are specially and artificially created by man for the fulfilment of different tasks. At the same time in the study of the sensitivity of the organism, the leading process is the process itself of the interaction of the signal and the living organism. Therefore, as the basis of the classification for the given case, it is appropriate to take the natural, actually existing signals and then divide them according to the basic qualitative and quantitative indices.

The concept of the signal as a material information carrier is closely connected with the concept of the form of movement of the matter. Therefore, it is natural to divide qualitatively the actually existing signals into a number of classes in conformity with the affiliation of them to the defined form of movement of the matter.

Five elementary forms of the movement of matter, studied by the appropriate sciences and their divisions, are known.

1. The movement of bodies - mechanics.
2. The movement of molecules - heat physics.
3. The movement of atoms in molecules - chemistry.
4. The movement of electrons - electricity, optics.
5. The movement of particles of a nucleus - nuclear physics.

Furthermore, as a result of the complication of the structure and function on earth, there exist three complex forms of the movement of matter:

1) biological - life of the organism;
2) psychic - consciousness of the organism;
3) social - life of the organism.

Their definite signals, which have a specific energy nature, correspond to each form of the movement of matter.

The division of the infinite multitude of signals into a number of groups makes it possible to be oriented in them easier but far from sufficient for the more accurate qualitative characteristic of the signal. Therefore, each form of the movement or, which is the same, each class of signals, must be subdivided into a definite quantity of subclasses, ranges and sections in conformity with generally accepted division.

This qualitative characteristic of any real signal can be called its "energy nature."

It is easy to see that the energy nature of the signal according to the given classification very closely coincides with sampling parameters accepted in the theory of the structure of the signals. However, in covering all forms of the movement of the matter, the classification cited here possesses a greater universality and is applicable to any real signals. Furthermore, the distinction of this parameter as the main characteristic of the signal makes it possible to underline its leading importance in the classification of the natural signals and also in the study of the perception of the signals by the organism.

Let us call the second most important quantitative characteristic of the signal its structure, i.e., the distribution of intensity of the signal with time. In general this function can be sufficiently complex; however, from a physiological viewpoint and also in the solution to the many technical problems, more important is the simplest case when the signal has the form of a square pulse of sufficient length and the receiver (instrument, animal, man) must accomplish an alternative selection - to determine the presence or absence of the signal. Such a signal of any energy nature has a number of quantitative parameters, the more important of which can be considered as: 1) intensity, 2)

duration, 3) rate of turning on and turning off.

With respect to each of these parameters, the signal can prove to be physiologically weak. Thus in the determination of the threshold of perception to the one being tested, there are presented signals of different intensity knowingly above the threshold duration, which are turned on and turned off quite rapidly. If in the course of such an experiment presented to the one being tested is a signal the intensity of which is lower than the threshold, then for a given person such a signal will be weak physiologically or "weak with respect to intensity." Established by this means are the mean statistical thresholds of the perception of man. If in a similar experiment there is presented to the testee a signal the intensity of which will knowingly be above the threshold but will sharply reduce its duration, then such a signal will also not be perceived by man, and it can also be considered physiologically weak or "weak with respect to duration" [3, 4]. Furthermore, with a gradual turning on and turning off of the signal there appears no perception in the person, even if the amplitude of the signal somewhat increases the threshold magnitude, and the duration is taken knowingly above the threshold. That is, the signal can prove to be "weak with respect to the transition characteristics."

In a number of cases a definite role is played by the change in intensity within the square pulse produced according to one or another rules. This characteristic of the elementary signal, which is square in shape, can be called the internal structure. The signal can be filled by square exponential pulses of definite parameters, modulated by any method, including variations in the frequency, phase, band, and so on. Such a complex signal needs a more detailed description. Thus, if used as the signal is an electrical field (qualitative characteristic), then it can be described quantitatively by three parameters: 1) intensity - field intensity (V/m, μV/m); 2) duration - time for which the field is turned on (seconds); 3) transitional characteristics - time of the turning on and turning off (seconds).

It is possible to complicate this simple signal by interrupting or changing the field strength according to any law. For example, the field strength can be periodically changed according to the sinusoidal law with modulation coefficients of 0 to 100%, i.e., the alternating field with its parameters is superimposed onto the permanent electrical field. The signal can be represented also by the sequence of the exponential pulses of the electrical field, the duration of each separate pulse being much less than the duration of the signal. Such a sequence of the exponential pulses of definite duration and repetition frequency can be filled by high-frequency oscillations of the electromagnetic field having their parameters and so on. In other words, in the case of the use of the complex signal, a detailed description of its internal structure has considerable importance.

Thus the signals, irrespective of their perception by the organisms, can be considered completely described if their basic parameters are indicated: 1) energy nature, i.e., an affiliation to the definite section of the specific form of movement of matter; 2) structure - amplitude of the signal, duration and transitional characteristics, and also the character of the filling or internal structure.

When the question of the perception of the signals by the organisms is considered, then besides the parameters listed, the very process of the interaction of the organism with the signal has significant importance. Man does not perceive a signal if:

1) The energy nature of the signal emerges outside the limits of the specific range of its sensitivity. Thus the electrical, magnetic, electromagnetic fields (with the exception of the optical and near infrared region), infra- and ultra-sound, flows of elementary particles and so on are not perceived by man.

2) The specific signal proceeds to the inadequate receptor (light or odor to the skin, sound to the eyes, taste substances to the organ of hearing, etc.).

3) Structural parameters of the signal in their totality

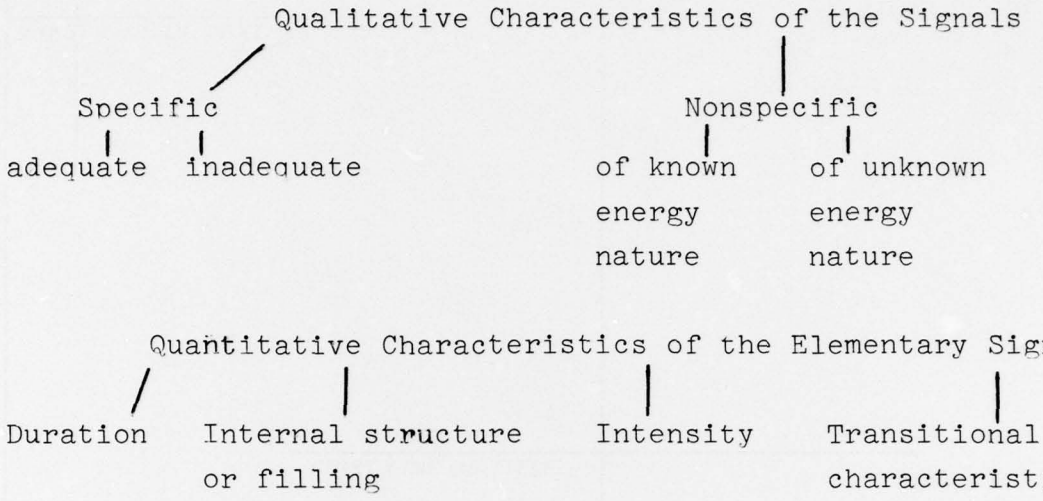
emerge outside the limits of the appropriate thresholds of man, i.e., the signal in the complete sense of the word is weak.

Corresponding to this, the signals not perceivable to man can be divided into three groups: 1) nonspecific; 2) specific inadequate; 3) weak specific.

It is easy to see that from the viewpoint of the perception by an organism, there is no difference between the nonspecific and inadequate signals, and if we examine the signals irrespective of their reception, then the inadequate and specific signals are also united into one group. However, methodically such a division with respect to the two criteria is sufficiently convenient.

In turn, the nonspecific signals can be divided into two groups: the known and still unknown energy nature. Referring to the first are the already listed signals (electromagnetic, ultrasonic, the odors not perceivable by man, cosmic rays, and so on). The signals of the unknown energy nature can be considered also those which precede earthquakes, volcanic eruptions and accompany changes in solar activity and certain other natural phenomena. These signals are objectively perceived by different animals and man, and under their effect definite physiological functions and the behavior of organisms are changed; however, we cannot as yet determine the energy nature of the signals. In the process of the accumulation of knowledge, the nonspecific signals, the nature of which is unknown, will gradually change over to a group of known signals. For example, the ability of a jellyfish to change its behavior ahead of time before a storm was found to be rather simple and associated with the perception of infrasonic noises of the sea.

In final form the classification of the natural signals from the viewpoint of their perception by organisms can be represented by the following diagram:




The proposed classification of the natural signals makes it possible to be somewhat better oriented in their infinite diversity and uniquely determine any real signal.

Thus the problem of the perception by the organisms of weak siganals is reduced here to the classification of the natural signals with respect to the qualitative and quantitative characteristics. This was necessary to do because of the fact that according to any of the parameters given above the signal can prove to be physiologically weak. Consequently, the term "physiologically weak signal" by itself is not unique.

The sensitivity of man to the specific adequate signals is considerably affected by their quantitative characteristics. In the region of the small times, the threshold sensitivity sharply increases along the force-duration curve and beginning from 10-30 ms becomes constant, being lowered with long signals as a result of the adaptation, i.e., with respect to the duration of the signal there is an optimum clearly limited in the region of small durations and weakly limited in the region of large durations [3, 5]. With respect to intensity a signal effect is possessed by stimuli the density of the flow of power of which is found in limits of $10^{-12}$-$10^{-3}$ W/m$^2$, having an optimum in the region of $10^{-7}$. With

respect to the internal structure, the more optimal signals can be considered the signals represented by a series of millisecond pulses following with a frequency of 300-400 pulses/s [6]. The slope of the fronts also has optimal values in a number of cases.

In generalizing the obtained data on the sensitivity of the organisms to the nonspecific signals, it is possible to assume that the found optimal values of the quantitative parameters of the signal for them are also applicable. An experimental check of this position showed that man can objectively perceive an electromagnetic field with a frequency of 735 kHz, modulated by a series of exponential pulses following with a frequency of 150 pulses/s with an average strength of 60 μV/m [8]. These data allow drawing the conclusion about the fact that the term "weak signal" from a physiological viewpoint generally is not correct, since the sensitivity of the organism is nonlinearly associated with the quantitative characteristics of the signals and has optimal values with respect to each of them.

In conclusion it is appropriate to discuss the principal difference in the two similar expressions "perception of weak sigals by the organisms" and "weak reactions of the organism with the reception of the signals." In the first case the topic of discussion is about the study of any reactions of the organism with the reception of the signal referred to the weak signal with respect to any parameter. The second definition emphasizes the methodical side of the work and characterizes the studies on the objective recording of the weak reactions of the organism to the action of any signal.

Unlike the first term, this term has a sufficiently clear value and can prove to be more convenient in the objective study of the sensitivity of the organisms.

Bibliography

1. Тарасенко Ф. П. Некоторые общие вопросы теории структуры сигналов. Тр. Сиб. физ.-техн. ин-та. Вып. 40, 1961, с. 3—7.

2. Тарасенко Ф П. Введение в курс теории информации. Томск, Изд-во Томского ун-та, 1963, 240с.

3. Макаров П. О. Нейродинамика зрительной системы человека. Л., Изд-во ЛГУ, 1952, 168с.

4. Макаров П. О. Нейродинамика человека. Л., Медгиз, 1956 214с.

5. Макаров П. О. Биофизика возбудимости органов чувств. Л., 1961. 68 с.

6. Плеханов Г. Ф., Денисов В. Н. и Опалинская А. Н. Теоретическое и экспериментальное определение характеристик сигналов, воспринимаемых организмами. Сб. трудов III конференции по бионике. М., «Наука», (в печати).

7. Соловьев Н. А. К вопросу о механизме биологического действия импульсов магнитного поля. Докл. АН СССР, т. 149, № 2, 1963, с. 438—441.

8. Плеханов Г. Ф. и Ведюшкина В. В. Выработка сосудистого условного рефлекса у человека на изменение напряженности электромагнитного поля высокой частоты. Журн. высш. нервной деятельности им. Павлова, т. 16, вып. 1, 1966, с. 34—37.

DISTRIBUTION LIST

DISTRIBUTION DIRECT TO RECIPIENT

| ORGANIZATION | | MICROFICHE |
|---|---|---|
| A205 | DMATC | 1 |
| A210 | DMAAC | 2 |
| B344 | DIA/RDS-3C | 8 |
| C043 | USAMIIA | 1 |
| C509 | BALLISTIC RES LABS | 1 |
| C510 | AIR MOBILITY R&D LAB/FIO | 1 |
| C513 | PICATINNY ARSENAL | 1 |
| C535 | AVIATION SYS COMD | 1 |
| C591 | FSTC | 5 |
| C619 | MIA REDSTONE | 1 |
| D008 | NISC | 1 |
| H300 | USAICE (USAREUR) | 1 |
| P005 | ERDA | 1 |
| P055 | CIA/CRS/ADD/SD | 1 |
| NAVORDSTA (50L) | | 1 |
| NASA/KSI | | 1 |
| AFIT/LD | | 1 |

| ORGANIZATION | | MICROFICHE |
|---|---|---|
| E053 | AF/INAKA | 1 |
| E017 | AF/ RDXTR-W | 1 |
| E404 | AEDC | 1 |
| E408 | AFWL | 1 |
| E410 | ADTC | 1 |
| E413 | ESD | 2 |
| | FTD | |
| | CCN | 1 |
| | ETID | 3 |
| | NIA/PHS | 1 |
| | NICD | 5 |